MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

DCE5028 – ELECTRICAL MACHINES AND POWER SYSTEMS

(Diploma in Electronic Engineering)

9 MARCH 2020
2:30 p.m. – 4:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of 5 pages excluding the cover page and appendix.
2. Answer **ALL** questions. All necessary working steps must be shown.
3. Write all your answers in the answer booklet provided.

Answer ALL questions (100 marks)

Question 1

a) A two-leg magnetic core with an air gap is shown in Figure 1. The depth of the core is 5 cm, the length of the air gap in the core is 0.07 cm, and the number of turns on the coil is 500. The relative permeability of the core is 967 and the effective air-gap area increases 6 percent because of fringing effect.

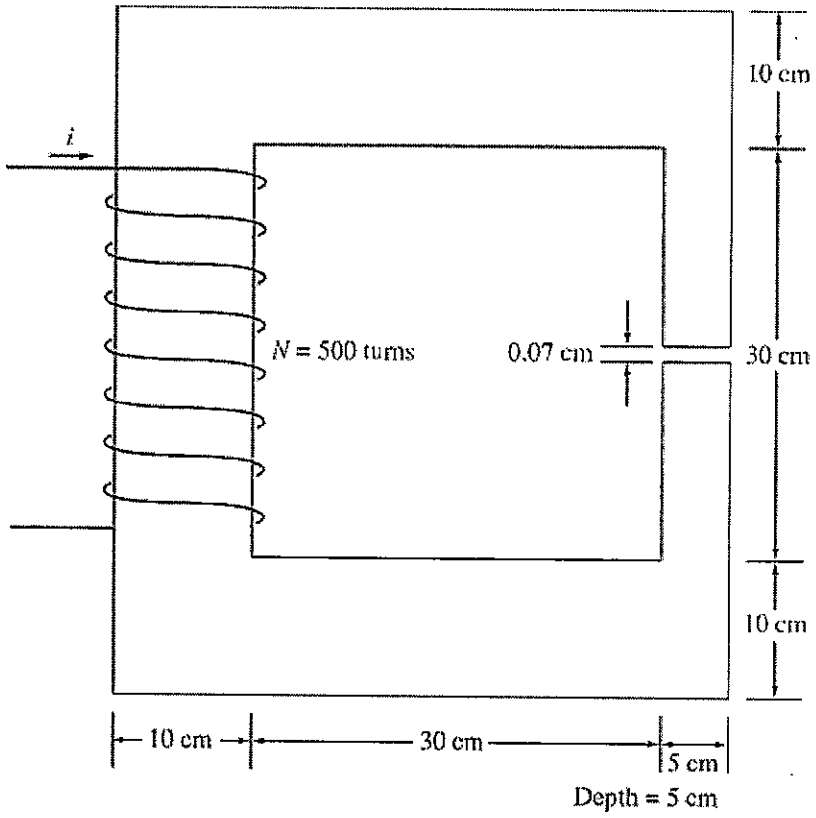

Figure 1

i. Draw the equivalent circuit for the magnetic system in Figure 1. [2 marks]

ii. Calculate total flux present if the air gap flux density is 0.66 T. [1 mark]

iii. Find the current flowing in the coil. [9 marks]

Continued...

b) Three identical impedances of 25 Ω with 0.75 power factor are star connected across three-phase, delta connected power supply of 317 V per phase. Determine:

i. the magnitude of line and phase voltage of the load, [3 marks]

ii. the magnitude of line and phase current of the load and supply, and [4 marks]

iii. the real power absorbed by the load. [1 mark]

[Total = 20 marks]

Question 2

a) A 100 kW, 230 V, DC shunt generator has armature resistance equal to 0.05 Ω and field resistance equal to 57.5 Ω . If the generator operates at rated voltage, calculate the induced voltage at the following condition:

i. Full load. [5 marks]

ii. Half-full load. [4 marks]

b) A 240 V DC motor has an armature resistance of 0.68 Ω and draws a full-load current of 24 A at a speed of 100 RPM. Calculate:

i. the back emf, [2 marks]

ii. the output power developed, and [2 marks]

iii. the torque developed. [2 marks]

[Total = 15 marks]

Continued...

Question 3

a) A 50 kVA, 2000/250V, 50 Hz, single-phase transformer has the following parameters:

Primary resistance = 1.15 Ω	Primary reactance = 3.5 Ω
Secondary resistance = 0.025 Ω	Secondary reactance = 0.06 Ω

i. Calculate the total resistance and reactance, referred to the secondary side. [3 marks]

ii. Find the secondary terminal voltage on full load at 0.8 lagging power factor. [4 marks]

b) Three identical transformers with each rated 6.6/22 kV, 3 MVA, are connected in Y-Y. The transformer bank is fed from a source of line voltage 11.43 kV at primary. The secondary side feeds a delta connected load composed of three equal impedances Z. Assuming the individual transformer to be ideal, find:

i. the value of Z in ohms to fully load to the bank, [4 marks]

ii. the phase current of the delta connected load, and [2 marks]

iii. the phase current in each transformer primary and secondary. [2 marks]

[Total = 15 marks]

Continued...

Question 4

a) A 4-pole 400 V, 50-Hz, three-phase induction motor runs at 1440 RPM at 0.88 lagging power factor and delivers 10.817 kW. The stator loss is 1060 W, and the friction and windage losses are 375 W. Calculate the following:

i. slip. [2 marks]

ii. rotor copper loss (P_{cu}), [2 marks]

iii. rotor frequency, [1 mark]

iv. line current, and [4 marks]

v. motor efficiency (η). [1 mark]

b) A 440 V, three-phase Y- connected synchronous motor has a synchronous reactance of 1.5 Ω per phase. The field current has been adjusted so that the torque angle δ is 28° when the power supplied to the motor is 90 kW. Calculate the following:

i. the magnitude of the internal generated voltage, E_A, in this machine, [4 marks]

ii. the magnitude and angle of the armature current in the machine, [3 marks]

iii. the motor power factor, and [1 mark]

iv. the maximum power this motor can supply if the field current remains constant. [2 marks]

[Total = 20 marks]

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Question 5

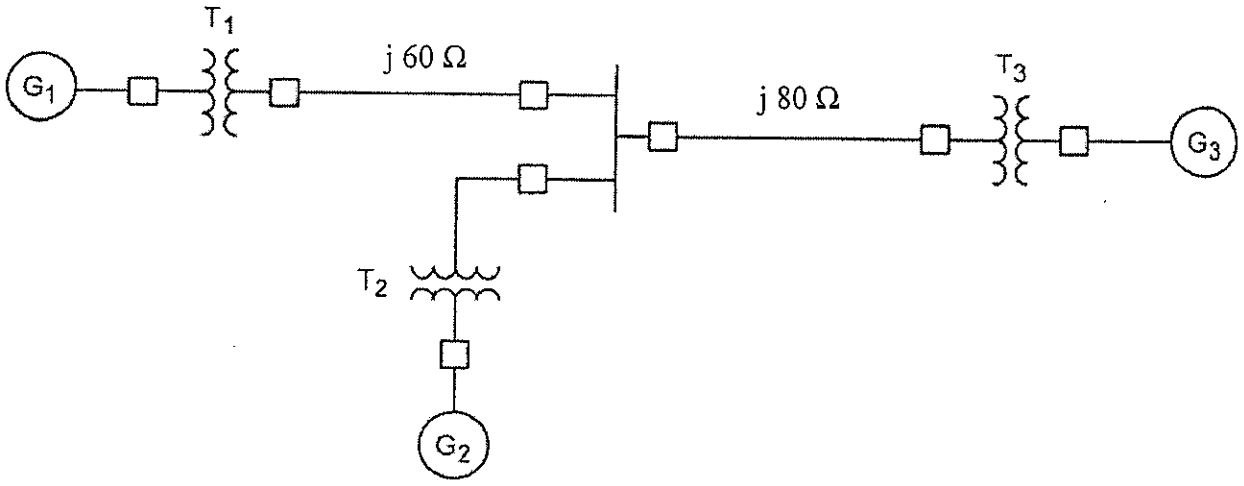


Figure 2

The single line diagram of a power system with reactance of the transmission lines are shown in Figure 2. The base values for this system are chosen to be 50 MVA and 13.8 kV at the Generator 1 side. The generators and transformers are rated as follows:

Generator 1: 50 MVA, 13.8 kV, X = 50 %
Generator 2: 30 MVA, 20 kV, X = 23 %
Generator 3: 28 MVA, 18 kV, X = 20 %
Transformer T1: 25 MVA, 13.8 / 220 kV, X = 10 %
Transformer T2: 35 MVA, 220 / 22 kV, X = 10 %
Transformer T3: 30 MVA, 220 / 18 kV, X = 10 %

a) Calculate the base voltage at every section of the power system. [7 marks]
b) Calculate the new per unit values for generators and transformers. [12 marks]
c) Calculate the base impedance of transmission line. [2 marks]
d) Calculate the new per unit values for all transmission lines. [6 marks]
e) Draw the per unit reactance diagram with all the calculated reactance values. [3 marks]

[Total = 30 marks]

End of page.

Appendix

Magnetic Circuit

$\mathbf{F} = Ni = \Re_{eq}.\Phi = Hl$ $\quad \Re_c = \frac{l_c}{\mu_c A_c}$ $\quad B = \frac{\Phi}{A_c}$

$\mu_c = \mu_r \mu_0$ $\quad \mu_0 = 4\pi \times 10^{-7}$ H/m

$E = \frac{\Phi ZN}{60} \times \frac{P}{A}$ $\quad \tau = \frac{1}{2\pi}\left(\frac{P\Phi Z}{A}\right) I_a$ $\quad P_M = \tau.\omega = EI_A = P_E$

DC Machines

$V_t = E - R_a I_a$ (Shunt Generator) $\quad \eta = \frac{P_{out}}{P_{in}} \times 100$

$V_t = E + R_a I_a$ (Shunt Motor)

Armature copper loss = $I_a^2 R_a$ $\quad$ Field copper loss = $I_f^2 R_f$

Transformer

$a = \frac{E_1}{E_2}$ $\quad V_2 = E_2 - I_2(R_{e2} + jX_{e2})$ $\quad R_{e1} = R_1 + a^2 R_2$ $\quad R_{e2} = \frac{R_1}{a^2} + R_2$

Voltage regulation = $\frac{E_2 - V_2}{V_2} \times 100$ $\quad X_{e1} = X_1 + a^2 X_2$ $\quad X_{e2} = \frac{X_1}{a^2} + X_2$

Three-phase Circuits

Δ: $\quad V_L = V_\phi$ $\quad I_L = \sqrt{3} I_\phi$

Y: $\quad V_L = \sqrt{3} V_\phi$ $\quad I_L = I_\phi$

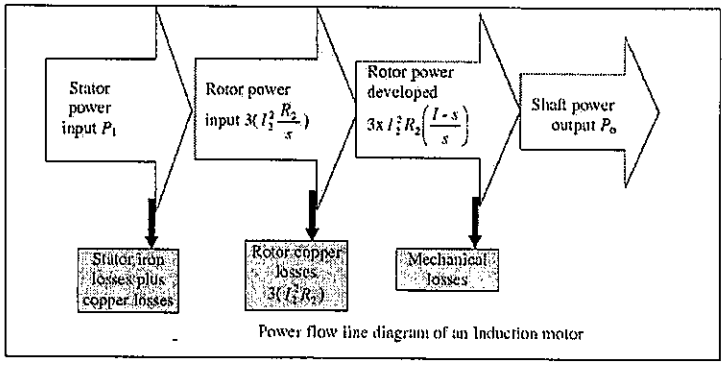
$S = 3V_\phi I_\phi = \sqrt{3} V_L I_L$

$P = 3V_\phi I_\phi \cos\theta = \sqrt{3} V_L I_L \cos\theta$

$Q = 3V_\phi I_\phi \sin\theta = \sqrt{3} V_L I_L \sin\theta$

Induction Motor

$n_s = \frac{120f}{p}$ $\quad s = \frac{n_s - n}{n_s}$


Stator power input P_1
Rotor power input $3(I_2^2 \frac{R_2}{s})$
Rotor power developed $3x I_2^2 R_2 \left(\frac{1-s}{s}\right)$
Shaft power output P_o
Stator iron losses plus copper losses
Rotor copper losses $3(I_2^2 R_2)$
Mechanical losses
Power flow line diagram of an Induction motor

Synchronous Machines

$X_S = \frac{E_{open-circuit}}{I_{short-circuit}}$

$P = \frac{E_c V}{X_s} \sin\delta$

$E_c = V - I_a(Ra + jX_S)$

Per-unit Value

$$per-unitZ_{new} = per-unitZ_{given}\left(\frac{basekV_{given}}{basekV_{new}}\right)^2\left(\frac{basekVA_{new}}{basekVA_{given}}\right)$$